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A DATABASE APPROACH TO
AIRCRAFT CARRIER AIRPLAN
PRODUCTION

by

Robert M. Stammer

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Thesis Advisor: CAPT G. W. Conner

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The Prototype model developed accepts inputs from the Assistant Strike Operations Officer. The model searches the database for airplans that conform to his inputs and provides candidate airplans for review. Once an airplan is selected, an airplan template, in spreadsheet format, can be altered to meet any required changes. Once changed to meet specific tasking the final product can be saved. After a period of operations the database search file can be updated to mold the database to a specific ship and airwing's standard operating routine.

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A DATABASE APPROACH TO AIRCRAFT CARRIER AIRPLAN PRODUCTION

by

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ABSTRACT

This thesis addresses a known problem in Carrier Aviation. The problem is the constant duplication of effort writing the carrier airplan. This problem is common to all airwings and results in late airplan publish times which reduce the combat effectiveness of the battlegroup. The analysis of the airplan is accomplished through the establishment of a database of carrier airplans. The database interacts with a spreadsheet designed to help Strike Operations aboard the carrier streamline the process of writing the airplan.

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THESIS DISCLAIMER

The reader is cautioned that the computer program developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the program is free of computational and logic errors, it cannot be considered validated. Any application of this program without additional verification is at the risk of the user.

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I. INTRODUCTION

A. PROJECT BACKGROUND

This Masters Thesis is written in partial response to a Chief of Naval Operations (OP-73) Tactics Development and Evaluation (TAC D & E) proposal. The proposal addresses a known problem within the Aircraft Carrier Aviation community of the United States Navy. The problem is inefficiency in the daily airplan production process. In addition to the duplication of effort in airplan production, late publish times for the airplan have repercussions seen throughout the ship, airwing and accompanying battlegroup. In many cases the individual warfare commanders, such as the air warfare or anti-submarine warfare commander, are not embarked on the aircraft carrier. They are dependent on the airplan to outline the aircraft assets they will have at their disposal. The overall effect of the airplan's late promulgation is lost productivity and reduced combat effectiveness for the battlegroup.

The carrier airplan is described in detail in following sections for the reader unfamiliar with carrier operations. The most basic explanation is that the airplan is the single approved flight schedule for the whole carrier airwing. Any flights originating and/or terminating aboard the aircraft carrier are scheduled via the airplan. The airplan directly or indirectly affects the actions of every person aboard the aircraft carrier and, in most cases, every ship in the accompanying battlegroup.

The airplan does not include actual names of aircrew flying each sortie, that is the responsibility of squadron operations departments. The airplan provides structure for each squadron's flight schedule. Publishing the airplan late forces squadron operations departments to hold production of their flight schedules. This forces similar reduction in combat effectiveness within the airwing.

The TAC D & E proposal addresses three problem areas. The first area is analysis of the airplan and the production process. This portion is to include factors which have direct and indirect affects on the daily airplan. Second, the proposal seeks to clarify which of these factors are quantifiable, if any. And, finally, the project should attempt to automate the production process. The proposal suggests a prototype model to be experimented with during an aircraft carrier workup phase. That model is to be followed by a full-scale working model.

B. CARRIER AVIATION INTRODUCTION

Aircraft carrier aviation consists of several facets of the Navy working together. An understanding of what the people and machines do and how they interact must be established, along with some vocabulary specific to carrier aviation. This is necessary to comprehend the analysis and recommendations to follow.

1. Vocabulary

- Airplan: The single approved flight schedule for the embarked airwing.
- Strike Operations: The office on the aircraft carrier that composes the daily airplan. The ship's focal point for all airplan information.
- Launch: Take off from aircraft carrier.

- Recover: Land on the aircraft carrier.

- Recovery: Actual landing of a group aircraft.

- Cycle: Period between successive launches, normally between one and two hours.

- Event: One or more aircraft launching with the same callsign.

- Flight: A group of two or more aircraft.

- Turnaround Time: Time needed to prepare a recovering aircraft for later launch.

- Deck: Refers to the flight deck of the aircraft carrier and its capability to accomplish flight operations

- PIM: Projected Intended Movement. Course and speed the ship must make over a determined period.

- Trap: Landing aboard the ship.

- Sortie: A mission accomplished by a single aircraft that launches and recovers aboard the carrier.

- Night Sortie: A sortie that recovers at night.

2. Aircraft Carrier

The aircraft carrier is organized into several departments that accomplish various tasks. Each of the following departments place constraints on the ability of the aircraft carrier to conduct flight operations. The Operations Department is responsible for the airplan. The actual production of the airplan is accomplished by Strike Operations (STKOPS) which is part of the Operations Department. The Operations Department gathers inputs from other departments aboard the ship, the warfare commanders, and other ships in the battlegroup. These inputs, along with standing

operating orders, or battlegroup commander requirements, form the structure for the next day's airplan.

There are two basic operating situations for the carrier battlegroup; independent battlegroup operations and combined command support. During independent battlegroup operations, the battlegroup commander, airwing commander and the carrier commanding officer set the tempo of operations for the carrier and the battlegroup. The battlegroup will accomplish training to maintain full combat readiness. For the airwing, these training requirements are outlined in the COMNAVAIRPAC/COMNAVAIRLANT Joint Training Instruction [Ref 1]. In the combined command support role, the carrier battlegroup commander is subordinate to a fleet or combined commander. In this case, the tempo of operations is set by the combined commander, and is promulgated through an Air Tasking Order (ATO). In either case, the Operations Department formulates the structure for the next day's airplan. The operating pace of the ship and airwing is reduced to four basic variables:

- Number of day cycles,
- Number of night cycles,
- Total number of sorties,
- Time flight operations will commence and secure.

It is then the task of the Assistant Strike Operations Officer (ASTKE) to meet all standing operating orders, ship imposed constraints, and any other known operating limitations while composing the next day's airplan. These constraints and limitations come from many areas. Air Operations (AIROPS), another division of the Operations

Department, functions much like civilian aviation air traffic controllers. AIROPS controls the airspace within fifty nautical miles of the carrier. They impose a maximum number of sorties allowed for any given recovery. This applies mainly at night. Duties also include:

- Track all airborne airwing assets within fifty miles of the carrier.
- Maintain location data on all other airborne tracks within fifty miles of the carrier.
- Maintain status board of all airwing assets.
- Control airborne tanking procedures.
- Maintain flight following radar in congested areas.
- Maintain status of aircraft in overhead pattern.
- Provide alternate landing field information to aircraft in need.

AIROPS could become overwhelmed if too many aircraft are airborne. In this way, AIROPS constrains the airplan. Too many airwing sorties airborne, or a combination of that and other limiting factors can severely restrict the airplan options.

Other departments aboard the ship also impact the airplan. The flight deck can only support a certain number of sorties for any given cycle, dependent on many factors. The Navigator determines the course and speed (PIM) the ship must make to meet scheduled commitments. Since flight operations can adversely affect the ability of the ship to make PIM, this can constrain the airplan. Other constraints are planned evolutions where flight operations are impossible, such as underway replenishment. The ship's non-aviation training requirements must also be considered.

ASTKE must organize all the inputs from the Operations Department to compose a viable airplan. What has evolved is a system of priorities. Each major contributor's input to the airplan is prioritized, and the requirements are met within constraints. Once each of these items is considered the airplan is written. The priorities are:

- Air Tasking Order or Battlegroup Commander Intentions.
- Warfare Commanders' Intentions.
- Ship's Training.
- Airwing Training.

The approval process subjects the airplan to careful scrutiny. The proposed airplan is initially checked by ASTKE. The next step is the Strike Operations Officer. He is most concerned with ships training and ensuring there is a sufficient number of certain missions for the ship to maintain special qualifications. Next, the airplan must win the approval of the Air Operations Officer. He ensures the airplan can be flown safely. His considerations include the number of aircraft airborne at any given time and the ability of the flight deck to ready aircraft for subsequent launches. The approving signature is the carrier Operations Officer. His focus is ensuring an overall flyable airplan and that all standing orders and tasking have been met. A diagram of the input and approval process can be seen in Figure 1.

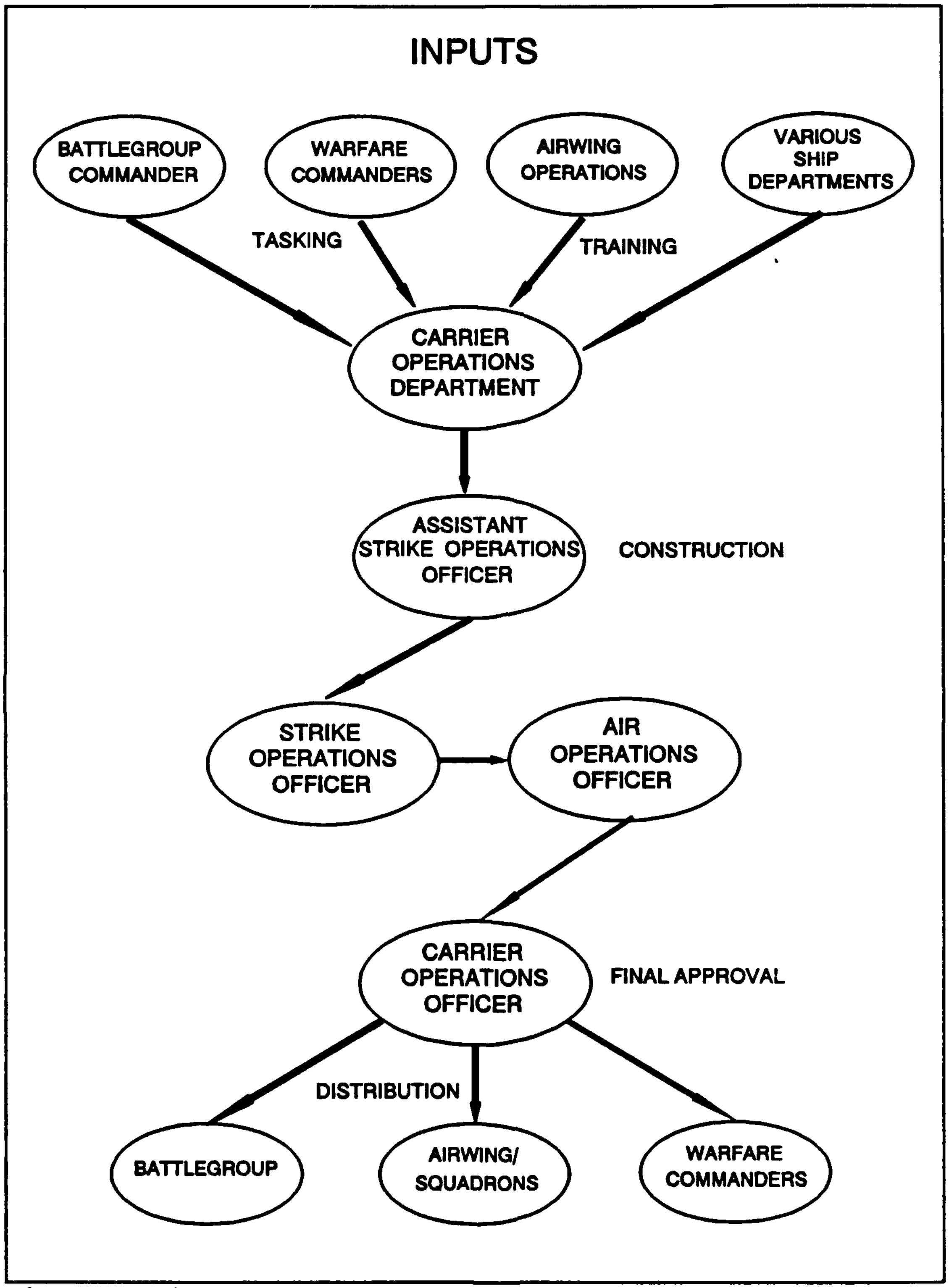


Figure 1 Airplan Approval Process

3. The Airwing

The aircraft carrier notional airwing consists of a mixture of multi-mission aircraft. Table 1 shows the notional airwing assets.

- Two squadrons of F-14A, Air Interceptors.
- Two squadrons of F/A-18D, Light Attack and Fighters.
- One Squadron of A-6E, Medium Attack and Tankers.
- One squadron of EA-6B, Electronic Countermeasures.
- One squadron of S-3B, Anti-surface and Subsurface, Tankers.
- One squadron of E-2C, Early Warning.
- One squadron of helicopters H-3 or SH-60F, Anti-submarine and Logistics.

The helicopters are not included in the analysis portion. Helicopter launches and recoveries do not have a significant impact on the airplan. The model proposed in Chapter IV accommodates all other assets common to the aircraft carrier including Carrier Onboard Delivery by fixed wing assets. The analysis is directed strictly at organic fixed wing assets.

The flight qualification of squadron pilots is an important factor in the daily airplan production. Safety requirements imposed by the Landing Signal Officer Naval Air Training Operations Program Standardization (LSO NATOPS) dictate that each squadron pilot fly a minimum of one night landing within a seven day period to remain eligible to fly at night from the aircraft carrier. If this minimum is not met, a series of flights must be performed to requalify a squadron pilot to become eligible to land at night. Responsibility for pilot night currency lies with squadron Operations Departments.

TABLE 1 NOTIONAL AIRWING

SQUADRON TYPE	AIRCRAFT TYPE	NUMBER OF AIRCRAFT	NUMBER OF A/C AVAIL	NUMBER OF SQN PILOTS
VF	F-14A	10 +/- 1	6 +/-	15
VF	F-14A	10 +/- 1	6 +/-	15
VFA	F/A-18D	11 +/	7 +/-	18
VFA	F/A-18D	11 +/- 1	7 +/-	18
VA	A-6E	10 ATTACK 3 TANKER	7 BOMBER 2 TANKER	14
VAQ	EA-6B	4	3 +/-	7
VS	S-3B	7 +/- 1	5 +/-	15
VAW	E-2C	4 or 5	3 +/-	10

They must manage night sorties/landings to maximize the number of night current pilots. Maintaining pilot night currency also places constraints on the carrier planning staff. The ship must, as a minimum, plan for 120 night sorties per seven day period.

Squadron maintenance departments must perform daily maintenance on aircraft for them to be mission-capable for subsequent flights. Aircraft turnaround time is a major limitation on the size of the daily airplan.

C. CARRIER AIRPLAN

The airplan can be described as a two dimensional array. Each element of the array is a complex entity that represents what a squadron is tasked to accomplish during

a specific period of the day. The periods, as defined earlier, are airplan cycles. The entities in each cell of the array are events, or flights of sorties.

Tasking often will determine the cycle time, which can vary throughout the day, but is usually between one and two hours. Cycle length has a direct impact on production of the daily airplan. The following list gives the potential impact a change in cycle time can have.

- Change necessary fuel loads for each aircraft type.
- Change airborne tanker requirements.
- Type and number of aircraft available for current and future missions. This is due to turnaround times.
- Combat Packages.
- Search area coverage and on-station time.
- PIM due to time into the wind for launch and recoveries.
- Amount of tactical training an event can accomplish due to fuel constraints.

One major problem with cycle time is that there is not a single length which best satisfies each squadron's operations and training requirements.

A callsign is assigned to each squadron event. It consists of a number, a letter, and another number. The first number determines launch cycle. The letter is the squadron identifier, A-H for organic airwing assets and X for logistics assets not actually part of the airwing. The final digit specifies events within each squadron. Figure 2 is a typical carrier airplan. Some information obtained from the airplan is listed below:

- Event callsign,

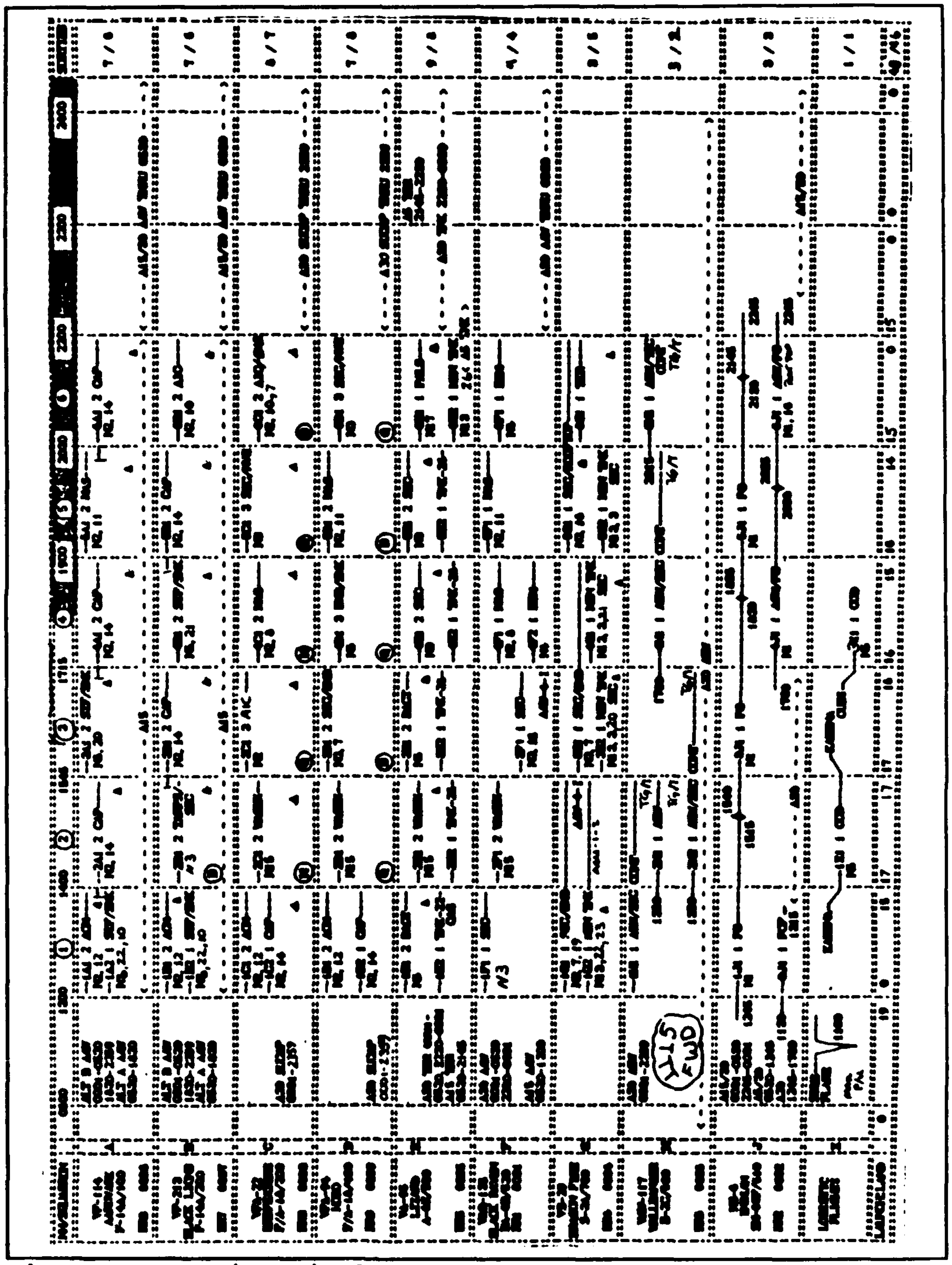


Figure 2 Carrier Airplan

- Number of aircraft in an event.
- Launch time.
- Recovery time.
- Fuel load if non-standard.
- Mission areas.
- Tanking requirements for each sortie.
- Combat Package/Ordnance loadout.
- Notes particular to each flight.
- Alert status.
- Emergency information.

D. GOAL

The goal of this thesis is to address the first two areas of the proposal and suggest a number of models for possible development by other thesis students from the following departments,

- Operations Research.
- Computer Science.
- Information Systems.

A prototype of one of the suggested models is included for evaluation.

E. APPROACH

The approach taken was to organize a number of airplans, then analyze aspects of the airplans to determine the factors that limit the daily production of the airplan. An

attempt is made to quantify those aspects that have the greatest influence on the difference between a feasible and unfeasible airplan. While it is obvious there could be numerous sortie mixtures on any given airplan, the goal is to characterize the typical airplan as closely as possible.

F. LIMITATIONS

As stated above, there are numerous possible sortie mixtures for any given set of airplan constraints. That number expands rapidly when all possible mission types are taken into consideration. The sheer size of the problem, and knowledge of the process, forces constraints from the outset.

These constraints are complexity, compatibility and cost limitations. First, the model should be easy to use for someone with basic computer knowledge. The model should also be small enough to run in a reasonable amount of time on a relatively small computer (386SX based IBM or compatible computer with one or two megabytes of random access memory). This is the class of computer normally available in the Strike Operations Office of an aircraft carrier. Finally, the software used for the prototype model should be multi-purpose, off the shelf, commercially available programs preferably already used on the carrier. If the end user has to purchase software, it was decided that the cost should be kept under $500.00.

II. DATABASE ESTABLISHMENT

A. INTRODUCTION

This chapter explores the structure of a database that will benefit mission planners in STKOPS. The carrier airplan is a dynamic document with inputs coming from numerous different areas. The structure of the database designed for storage of airplans is dependent on the intended use. A useable database structure was sought with two goals in mind, analysis of the airplan and airplan production. For airplan analysis, the format must allow quick calculations, sorting across numerous fields and convenient storage of statistics. For airplan production, the primary consideration was table look up, or query ability. The production phase will be addressed with the model recommendations.

B. DATABASE TERMINOLOGY

Before addressing the actual database structure, some terminology must be explained. A database can be thought of as a list of items with traits describing them. These items are called entities and the traits attributes. In other words, an entity is some object that occurs in nature. The object is made unique by assigning its attributes certain values. For example, assume a database is constructed of pilots in a squadron. The obvious entity would be the PILOT. The PILOT entity would have attributes such as, first, middle, and last names, department, rank, etc. Each of these attributes is given

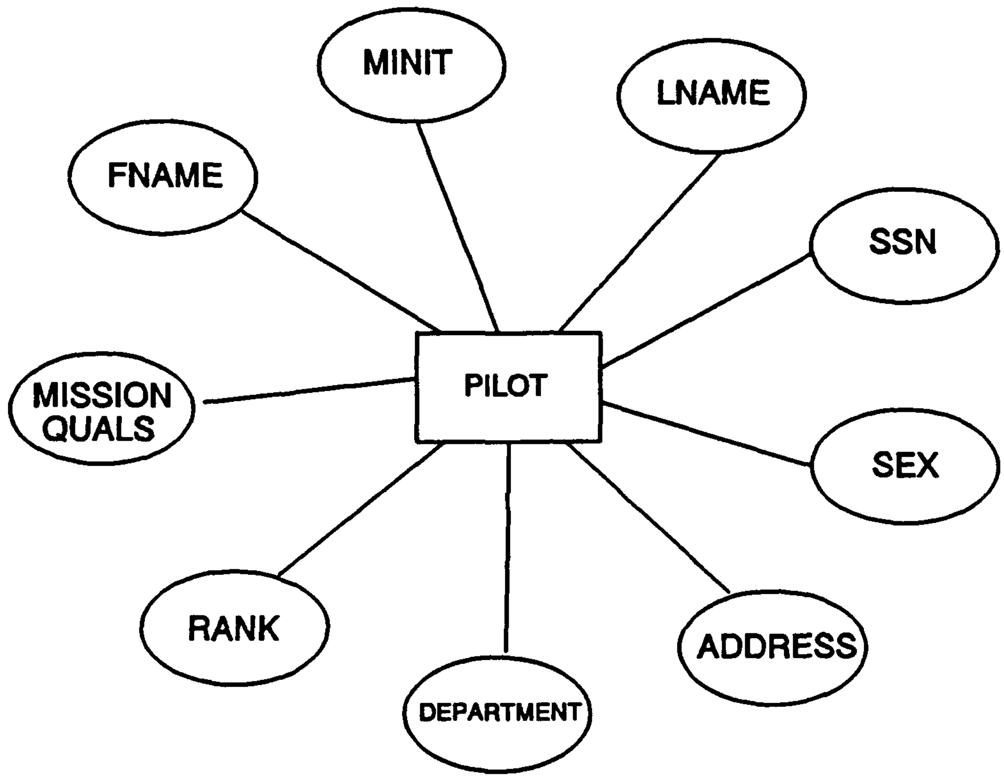
values in the database. Another way of picturing entities and attributes is to think of entities as rows of a table and attributes as columns. Figure 3 is a schematic of the PILOT entity. [Ref 2]

The most important factor in the construction of databases is the key. A key is an attribute or group of attributes that make an entity or row unique. In the PILOT example, a key is the Social Security number. The key uniquely determines each pilot in the squadron.

The power of well structured databases is the ability to quickly search through and find information about specific entities or groups of entities, and the ability to sort all files depending on attribute values. These processes are called queries and sorts. The ability to ask the database to produce all records that have a certain value for a specific attribute or to sort the database according to a certain attribute value provides the user quick access to significant amounts of information.

C. DATABASE SCHEMA

A tabular, or flat file, database structure was selected for use in this project. This was done with the end user in mind. The simple structure accomplishes the analysis and production goals listed earlier and should be easily understood by most users. The structure allows for quick sorting and queries without the complexity of an Object Oriented or Entity/Relationship database model. It also loosely follows the message format used for promulgating the airplan throughout the battlegroup after production.



PILOT

FNAME	MINIT	LNAME	SSN	SEX	ADDRESS	DEPT	RANK	QUAL

ATTRIBUTE VALUES

FNAME -- CHARACTER (10)
MINIT -- CHARACTER (3)
LNAME -- CHARACTER (15)
SSN -- NUMBER OF FORM ##-###-####
SEX -- CHARACTER (1)
ADDRESS -- CHARACTER (25)
DEPTARTMENT -- CHARACTER (15)
RANK -- CHARACTER (5)
MISSION QUALIFICATION -- CHARACTER (5)

Figure 3 Pilot Entity

1. The EVENT Entity

Referring to the airplan description, the basic element of the airplan is the sortie. Each sortie is an individual aircraft with a specific mission. The entity used for the basic record of the proposed database however, is the EVENT. Analysis determined that a majority of sorties launched were part of a flight, making up an event. The selection of the EVENT as the basic entity in the database eliminated many duplicate values, reduced the size of each file in the database, and eliminated the necessity of an additional attribute. The selection of the EVENT entity also conforms to the prototype model description in Chapter IV.

The EVENT entity, seen in Figure 4, is composed of number of attributes. The values for each attribute are also listed in Figure 4. Since the airplan data is stored in several different files, the uniqueness of each EVENT entity is important only in some respects. This problem is addressed in the discussion of the file types. Suffice to say, if individual flights are studied, where uniqueness is required, a DATE attribute can be added to achieve uniqueness. The addition of a DATE field is a simple extension of the current structure. In this case, the key for these entities is the combination of the DATE and CALLSIGN attributes.

2. AIRPLAN Files

The base file or storage file is the AIRPLAN file. Each of these files contains a list of EVENT entities that make up a single daily airplan. The file name

EVENT

CALL1	SQN	CALL2	QUAN	PMSN	SMSN	LCYC	RCYC	D OR N

VALUES

CALL1 -- INTEGER 1, 2, 3, . . .
SQN -- LETTER A-I ORGANIC X NON-ORGANIC
CALL2 -- INTEGER 1, 2, 3, 4
QUANTITY -- INTEGER 1, 2, 3, . . .
PRIMARY MISSION -- SEE APPENDIX A
SECONDARY MISSION -- SEE APPENDIX A
LAUNCH CYCLE -- INTEGER 1, 2, 3, . . .
RECOVER CYCLE -- INTEGER 1, 2, 3, . . .
DAY OR NIGHT -- BINARY 0 - DAY , 1 - NIGHT

Figure 4 Event Entity

corresponds to a date in the form MMDDYY. The actual date is not important but the uniqueness of the date is. The date is the key element for finding an individual airplan to analyze or reproduce. Within the AIRPLAN files the key attribute for the EVENT entity is the callsign.

D. DATA OBTAINED

The data consists of six months of deployment airplans. The deployment was made by Carrier Airwing 11 (CVW-11) embarked in USS Abraham Lincoln (CV-72) to the Pacific and Indian Oceans during May through November of 1991. This was considered a typical Western Pacific, peace time deployment. While the Persian Gulf War was in the recent past, this had little effect on how business was conducted during this deployment.

Approximately 110 airplans were obtained. The 110 airplans vice the 180 days that make up six months, is explained by taking into account inport periods. It is not uncommon for 30 or 40 percent of a peacetime deployment to be spent in foreign ports.

Some of the 110 airplans were eliminated, most because they were no-fly days or minimum fly days. These airplans, from experience, do not represent normal business aboard the carrier. Furthermore, production of these airplans does not pose a great problem for Strike Operations. After this, 75 airplans remained. Most structure oriented information was taken from the 75 remaining airplans. Detailed analysis was then conducted on 34 airplans.

III. AIRPLAN ANALYSIS

A. APPROACH

The airplan can be viewed as columns, rows or individual blocks. Each of these views is taken in the analysis of the individual airplan files. Each view gives insight into a different facet of the airplan and carrier operations in general. If columns are considered, the information derived from a number of airplans refers to cycle comparisons such as average number of launches per cycle. Squadron launch averages can also be obtained along with how these affect the airplan throughout the day. Analysis along rows yields information concerning individual squadron operations and how they compare. Total number of sorties per squadron, and the day and night sortie breakdown, are the primary pieces of information obtained from horizontal analysis of the airplan. Individual block analysis of the airplan focuses on mission areas, squadron operating procedures and sortie duration. This enables the analyst to compare, on a sortie by sortie basis, how different squadrons and/or aircraft types differ in their operating procedures. Individual sortie analysis also allows the analyst to characterize each airplan with an emphasis on mission area.

The goals of the analyses were to gain insight into enough facets of the airplan to make recommendations on possible ways to improve the production process. In addition to insight, it was necessary to ensure that the airplans obtained were a reasonable sample of the overall population. The fact that the airplans obtained were actually approved and

flown may make the second goal seem trivial, but approval alone is no guarantee that an airplan is "good." It would be less than optimal to start out with a group of substandard airplans.

B. ORGANIZATION

The airplans were obtained in standard hard copy airplan format. After the structure was established, approximately one hour was needed to transfer a hard copy airplan to a computer format that could be used for analysis. The transformation to a working data set was accomplished in Paradox 3.5, the software choice for the database portion of this thesis and model development.

Initially, the data analysis was structure oriented. Total cycles, total sorties and day night ratios from the 75 airplans were examined in an attempt to limit unnecessary data entry. From this initial examination of the airplans, a cursory definition of a standard airplan was made. Table 2 shows the results. It was determined that further analysis and subsequent model development should be structured around the standard (average) airplan. Table 2 shows the standard airplan to have four day cycles, three night cycles and approximately 85 sorties flown throughout the day.

A group of 34 airplans was organized into individual airplan files. The files are constructed of the EVENT entities that make up a daily airplan. From this format, the files were merged and sorted for the analysis of each area. The merging of the daily airplans took place in Quattro Pro 3.0. Quattro Pro was chosen for its built-in ability to communicate with Paradox 3.5, and for its ability to perform complex logical

TABLE 2 CYCLE AND SORTIE INFORMATION

	DAY CYC	DAY SORT	SORT/ DCYC	NITE CYC	NITE SORT	NSORT/ NCYC	TOT CYC	TOT SORT
AVG	4.33	44.24	14.75	2.9	40.13	13.87	7.23	84.36
STD DEV	1.06	15.01	5.00	0.80	12.14	2.04	1.07	16.13
MAX	7	84	26.33	5	69	19.67	10	140
MIN	1	16	6	1	11	8	4	59

selections and basic statistical calculations. Using the spreadsheet environment made parsing the data easier.

1. DAILY Files

As stated above, a file was made with the contents of each individual daily airplan. These files are used in the production application. The information is needed from each airplan to form the other analysis files. Data such as number of day and night cycles, total sorties, and overall mission percentages are used by the production application to characterize an airplan for future use. This information is presented in Table 3. Table 4 is a portion of a DAILY file.

2. OVERALL File

A file of all recorded events was made by combining the DAILY files. This OVERALL file contains all events in the database. The size of the file precluded its use

TABLE 3 DATABASE SEARCH FILE

DATE	DC	NC	TSO	NS	AC	AE	AIC	AS	BM	CAP	CQ	DAQ	DAC	ES	FA	FCF	LWL	MA	MT	NAV	NV	RAI	SSC	STR	SVC	TNK	TG/
06/29/91	2	3	68	45	9.2	4.6	4.6	0	18	12	0	9.2	0	1.5	0	3.1	0	9.2	4.6	0	0	0	18	6.2	0	6.2	0
07/26/91	2	4	70	53	0	5.7	14	0	21	1.4	0	0	5.7	5.7	0	1.4	0	0	7.1	0	0	0	27	0	0	7.1	2.9
06/14/91	2	5	105	68	13	3.8	9.5	6.7	5.7	1.9	0	3.8	0	3.8	0	1	0	13	7.6	0	3.8	1.9	20	6.7	5.7	3.8	1.9
06/23/91	3	2	56	30	0	7.1	25	0	0	0	100	0	0	1.8	0	1.8	0	0	0	0	0	0	13	0	0	14	0
06/26/91	3	3	91	45	6.6	4.4	9.9	0	18	13	0	4.4	0	4.4	0	2.2	0	11	5.5	0	6.6	0	30	5.5	1.1	6.6	0
06/02/91	3	3	95	46	9.5	5.3	26	0	13	0	0	0	2.1	2.1	0	0	0	5.3	3.2	12	2.1	0	25	0	4.2	6.3	29
07/08/91	3	3	83	48	0	6	9.6	0	16	19	0	0	0	2.4	0	0	0	0	6	0	0	23	39	2.4	0	6	3.6
07/27/91	3	3	66	40	0	6.1	15	0	23	1.5	0	0	6.1	4.6	0	0	1.5	0	6.1	0	0	7.6	24	0	0	11	4.6
07/25/91	3	4	72	53	0	5.6	17	0	31	1.4	0	0	5.6	5.6	0	0	0	0	5.6	0	0	0	28	0	0	13	5.6
06/28/91	4	0	70	0	0	5.7	2.9	0	5.7	14	0	5.7	0	1.4	0	2.9	0	0	8.6	0	0	2.9	8.6	0	1.4	5.7	0
07/14/91	4	3	84	43	0	6	14	0	6	7.1	0	4.8	0	4.8	0	0	29	0	3.6	0	0	0	18	0	0	13	11
07/09/91	4	3	77	44	0	5.2	0	0	7.8	21	0	0	0	1.3	0	1.3	0	0	6.5	0	5.2	32	32	0	10	6.5	2.6
07/28/91	4	3	85	42	0	3.5	16	0	2.4	0	0	4.7	0	3.5	0	1.2	5.9	0	5.9	0	0	0	22	0	0	8.2	2.4
07/16/91	4	3	71	40	0	7	17	0	14	11	0	2.8	0	2.8	0	0	11	0	4.2	0	0	0	24	0	0	14	4.2
07/21/91	4	3	82	42	0	4.9	7.3	0	27	13	0	4.9	0	4.9	0	1.2	0	1.2	11	0	0	8.5	6.1	0	0	11	4.9
07/22/91	4	3	80	43	0	5	10	0	28	15	0	0	0	5	0	3.8	0	0	8.8	0	0	16	8.8	0	0	13	5
06/27/91	4	3	94	46	8.5	5.3	7.5	0	9.6	13	0	4.3	0	2.1	0	0	0	8.5	5.3	0	6.4	0	26	6.4	0	6.4	0
06/05/91	4	3	73	53	16	2.7	5.5	5.5	21	0	0	0	0	2.7	0	0	0	14	2.7	15	6.9	0	14	0	0	5.5	2.7
07/06/91	4	3	98	48	0	3.1	2	0	2	12	0	0	4.1	2	0	1	2	7.1	7.1	0	2	3.1	31	2	12	6.1	9.2
07/07/91	4	3	83	48	0	4.8	9.6	0	14	14	0	2.4	0	3.6	0	1.2	0	4.8	4.8	0	0	9.6	36	0	9.6	6	3.6
06/25/91	4	4	119	60	6.7	3.4	0	0	16	13	0	5	0	0	0	0.8	0	24	5.9	0	4.2	0	30	1.7	0	6.7	0.8
06/04/91	4	4	81	63	15	3.7	14	4.9	17	0	0	0	0	2.5	0	0	0	12	3.7	8.6	4.9	0	12	0	0	6.2	3.7
07/13/91	5	2	71	28	0	8.5	30	0	0	0	0	0	0	4.2	93	0	0	0	4.2	0	0	0	28	0	0	8.5	0
08/05/91	5	3	89	39	0	4.5	15	0	6.7	10	0	0	11	4.5	0	1.1	5.6	1.1	5.6	0	0	0	24	0	4.5	9	3.4
07/31/91	5	3	80	36	5	3.8	23	0	14	8.8	0	0	0	3.8	0	1.3	0	0	1.3	0	0	0	24	0	0	16	0
07/30/91	5	3	83	37	4.8	4.8	19	0	7.2	11	0	0	12	3.6	0	0	6	0	2.4	0	0	0	23	0	0	13	3.6
08/04/91	5	3	64	41	0	4.7	19	0	6.3	11	0	0	9.4	1.6	0	0	11	1.6	4.7	0	0	0	17	0	7.8	9.4	3.1
07/20/91	5	3	96	51	0	4.2	11	0	22	9.4	0	4.2	0	1	0	5.2	4.2	0	10	0	0	0	13	0	0	11	4.2
06/12/91	5	3	120	48	13	3.3	23	4.2	7.5	0	0	3.3	0	1.7	0	0.8	0	15	2.5	0	0	0	20	0	3.3	5.8	2.5
08/07/91	5	3	85	36	12	4.7	14	0	12	11	0	0	7.1	3.5	0	1.2	1.2	1.2	4.7	0	0	0	22	0	0	12	2.4
07/17/91	5	4	81	45	0	6.2	23	0	7.4	9.9	0	2.5	0	2.5	0	0	0	0	6.2	0	0	0	22	0	0	14	6.2
06/06/91	6	2	97	18	19	2.1	3.1	0	13	0	0	0	0	1	0	1	0	11	5.2	9.3	0	0	18	2.1	0	7.2	0
06/03/91	6	4	130	58	0	3.1	18	0	17	0	0	0	1.5	2.3	0	0	0	7.7	2.3	10	4.6	0	15	0	0	6.9	0
07/29/91	7	0	85	0	0	5.9	25	0	7.1	0	0	4.7	0	5.9	0	0	0	0	5.9	0	0	0	25	0	0	14	0

TABLE 4 DAILY FILE

C/S	QUA	TOTMSN	RCY	LCYC	C1	SQN	C2	PMSN	SMSN	D/N
1A1	2	ACM,TG/T	2	1	1	A	1	ACM	TG/T	0
1B1	2	ACM,TG/T	2	1	1	B	1	ACM	TG/T	0
1C1	2	ACM,TG/T	2	1	1	C	1	ACM	TG/T	0
1D1	3	ACM,TG/T	2	1	1	D	1	ACM	TG/T	0
1E1	1	TNK,TG/T	3	1	1	E	1	TNK	TG/T	0
1E2	2	ULT,TG/T	2	1	1	E	2	ULT	TG/T	0
1F1	2	DACM,TG/	2	1	1	F	1	DACM	TG/T	0
1G1	1	SSC,BMB	3	1	1	G	1	SSC	BMB	0
1H1	1	AEW,TG/T	3	1	1	H	1	AEW	TG/T	0
2A1	3	AIC,TG/T	3	2	2	A	1	AIC	TG/T	0
2B1	2	NAV,TARP	3	2	2	B	1	NAV	TARPS	0
2C1	2	SSC,TG/T	3	2	2	C	1	SSC	TG/T	0
2C2	1	SVCS	3	2	2	C	2	SVCS		0
2D1	2	AIC,BMB	3	2	2	D	1	AIC	BMB	0
2E1	2	NAV,TG/T	3	2	2	E	1	NAV	TG/T	0
2E2	1	TNK	3	2	2	E	2	TNK		0
2F1	1	SSC	3	2	2	F	1	SSC		0
2G1	1	SSC,BMB	4	2	2	G	1	SSC	BMB	0
2G2	1	MTNK,TG/	3	2	2	G	2	MTNK	TG/T	0
2H1	1	AEW,SSC	4	2	2	H	1	AEW	SSC	0
3A1	2	NAV,TG/T	4	3	3	A	1	NAV	TG/T	0
3B1	2	AIC,TG/T	4	3	3	B	1	AIC	TG/T	0
3C1	3	AIC	4	3	3	C	1	AIC		0
3D1	2	AIC	4	3	3	D	1	AIC		0
3D2	1	SVCS	4	3	3	D	2	SVCS		0
3E1	2	SSC,BMB	4	3	3	E	1	SSC	BMB	0
3E2	1	TNK	4	3	3	E	2	TNK		0
3F1	2	SSC	4	3	3	F	1	SSC		0
3G1	1	NAV,TG/T	4	3	3	G	1	NAV	TG/T	0
4A1	2	AIC	5	4	4	A	1	AIC		1
4B1	2	SVCS	5	4	4	B	1	SVCS		1
4C1	2	NAV	5	4	4	C	1	NAV		1
4D1	2	NAV	5	4	4	D	1	NAV		1
4E1	2	BMB,SSC	5	4	4	E	1	BMB	SSC	1
4E2	1	TNK	5	4	4	E	2	TNK		1
4F1	1	SSC	5	4	4	F	1	SSC		1
4G1	1	SSC	6	4	4	G	1	SSC		1
4H1	1	AEW,SSC	6	4	4	H	1	AEW	SSC	1
5A1	2	MAS	6	5	5	A	1	MAS		1
5B1	2	AIC	6	5	5	B	1	AIC		1
5C1	2	SSC,NVG	6	5	5	C	1	SSC	NVG	1
5D1	2	MAS	6	5	5	D	1	MAS		1
5E1	2	SSC,BMB	6	5	5	E	1	SSC	BMB	1
5E2	1	TNK	6	5	5	E	2	TNK		1
5F1	1	ESM	6	5	5	F	1	ESM		1
5F2	1	MAS	6	5	5	F	2	MAS		1
5G1	1	SSC	7	5	5	G	1	SSC		1
5G2	1	MTNK	6	5	5	G	2	MTNK		1
5H1	1	AEW,SSC	7	5	5	H	1	AEW	SSC	1
6A1	2	AIC	7	6	6	A	1	AIC		1
6B1	2	AIC	7	6	6	B	1	AIC		1
6C1	3	AIC	7	6	6	C	1	AIC		1
6D1	2	AIC	7	6	6	D	1	AIC		1
6E1	2	SSC,BMB	7	6	6	E	1	SSC	BMB	1
6E2	1	MTNK	7	6	6	E	2	MTNK		1
6F1	1	ESM	7	6	6	F	1	ESM		1
6G1	1	SSC	7	6	6	G	1	SSC		1
6G2	1	TNK	7	6	6	G	2	TNK		1
6H1	1	AEW	7	6	6	H	1	AEW		1

for all but the simplest calculations. This file was used to obtain overall airwing statistics. The size of the file and nature of the final use allowed structuring the OVERALL file without a DATE field. If the records of the OVERALL file were required to be unique, a "DATE" field could easily be added. During analysis of the OVERALL file the decision was made to eliminate sorties that did not both launch and recover on the carrier. As discussed earlier these type flights, due to their small number, along with the helicopter sorties, do not have a proportionally large impact on daily flight operations.

3. SQUADRON Files

A file was also formed for each squadron. These files are made up of all events flown by each squadron. The files were obtained by sorting the OVERALL file on the squadron letter attribute. These files have little use to the scheduler on a daily basis, but they allow collection of individual squadron statistics over an extended period. This information is useful for comparison within the airwing and for comparison with published Navy training requirements. The comparison with Navy training and readiness requirements helps ensure that each squadron is provided the opportunity to maintain full mission capable aircrew.

Analysis of the squadron files allowed a close look at mission areas flown by each squadron. In the case of the F-14 and F/A-18 squadrons, comparisons between sister squadrons were made. This mission data was important when designing the interface with the database of previously flown airplans, because the published

requirements for mission readiness in each mission area can be used as scheduling guidelines.

C. TECHNIQUES USED

In each of the files, it was necessary to use logical comparisons to gather information from the data. The logical functions of Quattro Pro proved invaluable in this process. The statistical functions of the Quattro Pro spreadsheet package also proved useful. Appendix B contains the functions and macros used in the analysis. Numerous samplings were taken from the data. The analysis was approached by extracting as much information as possible from each file according to the file type. The results are discussed in a similar fashion.

1. DAILY files

Statistics were collected on the DAILY files with the goal of characterizing a typical daily airplan. This characterization was needed for two reasons. The first reason is for comparison with the combined data, or the OVERALL file. The second use is in distinguishing airplans in a way that would be helpful during airplan production. This characterization is accomplished using the parameters with which the ASTKE structures each day's airplan. These parameters are:

- Number of day cycles
- Number of night cycles,
- Number of total sorties.
- Time flight operations will commence.

The time will not be part of the analysis but it is accommodated by the prototype model. The reason for this is the that the hour when flight operations commence or terminate is not as important as the number of day and night cycles. In addition to the above listed parameters, three others were examined, night sorties, squadron totals and mission influences. Night sortie importance to maintain pilot night currency was discussed earlier. Mission influences further differentiate one airplan from another. Squadron total sortie information for comparison with training requirements.

It was thought that the distribution of sorties among squadrons would be a good descriptor of the airplan. After initial analysis, however, it was discovered it is not. This measure proved fairly constant. Table 5 shows these results. These results also match, with reasonable tolerance, the expected distribution from Reference 3. The close match between the equitable distribution and the actual distribution tends to validate the acceptability of the airplans used.

The numbers and types of cycles and sorties are additional input data. The analysis consisted of gathering the totals from the daily airplans and calculating the necessary statistics. The mission data, however, was not straight-forward. The mission data was extracted via logical comparisons in all stages of the analysis. At this stage, the mission data was extracted to help describe a certain airplan. The logical comparisons used to extract mission data can be found in Appendix B. This information is helpful in picking an airplan from the database for production.

TABLE 5 AIRWING SORTIE DISTRIBUTION

	VF-1	VF-2	VFA-1	VFA-2	VA	VAQ	VS	VAW
DAY AVG	5.91	5.71	6.71	6.59	7.74	3.44	4.32	2.26
DAY STD DEV	2.77	2.67	2.93	2.95	3.18	1.54	2.43	1.04
DAY MAX	13	13	12	13	14	6	12	5
DAY MIN	2	0	2	2	2	1	0	0
NIGHT AVG	5.74	5.59	6.38	6.56	7.91	3.15	4.97	2.35
NIGHT STD DEV	2.05	2.12	2.44	2.29	2.90	1.26	2.02	0.97
NIGHT MAX	9	9	10	10	12	6	9	5
NIGHT MIN	0	0	0	0	0	0	0	0
TOTAL AVG	11.6	11.29	13.09	13.15	15.65	6.59	9.29	4.62
TOTAL STD DEV	2.36	3.38	2.99	2.92	3.17	1.7	2.15	0.64
TOTAL MAX	19	20	22	22	24	11	14	6
TOTAL MIN	8	0	8	8	12	4	4	3
COUNT	34	34	34	34	34	34	34	34

2. OVERALL File

Once all the daily files were combined, the total number of events was 2176. The total number of sorties flown from these events was 3258. This yields an average of 1.49 sorties per event. The standard deviation on this average was 0.58 sorties.This information shows that the airwing, overall, launches with either one or two aircraft most of the time. This fact helped determine the use of the EVENT entity as the basic entity of the database for the analysis and prototype production model.

An interesting piece of information from the overall file was the day to night sortie ratio. Of the 3258 sorties entered into the database, 1619 recovered at night. This high percentage of night sorties, 49.7 percent, shows the attempt being made to maintain pilot night currency and the ability of the airwing to operate at night. "Was the high percentage of night sorties planned or did tasking work out to provide sufficient day to night ratio?" A discussion with the Assistant Strike Operations Officer on the Abraham Lincoln answered this question. The policy used during this period of operations was to schedule the airplan as tasked without regard for night landings. If airwing pilot night currency began to suffer, only then was emphasis placed on maximizing the number of night sorties within the constraints applied by AIROPS. Some of the costs associated with flying too many night sorties are often overlooked. Night flight operations are not only significantly more dangerous than day operations they also are less productive. Time is wasted in the holding pattern or Marshall stack. This flight time could be use more efficiently. Time spent in the Marshall stack by night sorties could have been used for secondary mission area completion. When the airplan can be analyzed, along with

other related statistics such as percent pilots night current, this area will be more useful. The data needed for this analysis is not available now.

The OVERALL file produced the airwing's average sorties per event, average number of cycles flown per event and the associated deviations for each. These allow the analyst to estimate the number of flight hours flown by the airwing for each airplan in the database. This also allows an estimate of the number of events that normally launch in any cycle. Given the constraints placed on the airplan by Air Operations of approximately 15 sorties per night recovery, one can estimate the number of events allowed to launch during any given cycle.

The final area of interest in the OVERALL file was the mission data. This information was extracted from the file through a series of logical comparisons. The mission portion of the airplan can be broken down into three areas, primary, secondary and tertiary. Every event has a primary mission. While every aircraft is capable of accomplishing multiple missions on a single sortie, the assignment of secondary and tertiary missions depends several factors. Analysis showed the number of secondary and tertiary missions was relatively small compared to the number of aircraft that are multi-mission. Only 863 of 3258 sorties or 26.5 percent had official secondary missions and 63 or 2.6 percent had tertiary missions. The decision was made to discard tertiary missions as a critical factor in the analysis and production phase of the airplan. The model has capability to accommodate tertiary missions, but the analysis will not include them.

Table 6 shows the overall mission breakdown for the airwing. Appendix A contains short a explanation of each mission area. The primary and secondary missions were given the same weight in the analysis; no added weight is given to either mission based on its relative position on the airplan. This is strictly a count of actual times a mission occurred on the airplan.

A byproduct of the mission data analysis is the number of mission areas needed to cover the airwing's tasking and training. Twenty-three mission areas account for approximately 94 percent of airwing flights. These numbers will be compared with squadron mission statistics in the next section.

3. SQUADRON Files

The SQUADRON files gave valuable insight into sortie and mission distributions. These files lend credence to each specific airplan's validity. As seen in Table 5, the comparison between sister squadrons was within one half of a percent in both cases. The distribution of sorties throughout the airwing comes close to the mix required to maintain aircrew qualifications. Table 7 shows total sortie numbers by squadron. Again, the comparison made between sister squadrons tends to validate the airplans used.

SQUADRON files provided another chance to analyze mission data. A similar technique to gathering mission data was applied to each of the SQUADRON files. Table 8 shows the distribution of each mission area over the airwing.

TABLE 6 COMBINED MISSION AREA PERCENTAGES

	ACM	AEW	AIC	ASW	BMB	CAP	CQ	DACT	EX	ESM	FCF	LWLV
PRIM MSN	125	151	460	18	249	203	45	129	95	69	43	68
% TOT	3.84	4.64	14.12	0.55	7.64	6.23	1.38	3.96	2.92	2.12	1.32	2.01
SEC MSN	12	2	27	2	144	28	166	0	13	29	0	0
% TOT	1.39	0.23	3.13	0.23	16.69	3.24	19.24	0	1.51	3.36	0	0
TOT	137	153	487	20	393	231	211	129	108	98	43	68
%TOT	3.32	3.71	11.82	0.49	9.54	5.61	5.12	3.13	2.62	2.38	1.04	1.65

TABLE 6 CONTINUED

	MAS	MSN TNK	NAV	NVG	SSC	TG/T	TARP	TNK	SVCS	STK	YO-YO	TOT PCNT (1)
PRIM MSN	174	162	49	0	586	0	35	237	70	96	2	
% TOT	5.34	4.97	1.50	0	17.96	0	1.07	7.27	2.15	2.95	0.06	94.10
SEC MSN	5	5	4	44	126	122	9	47	3	4	24	
% TOT	0.58	0.58	0.46	5.10	14.6	14.14	1.04	4.45	0.35	0.46	2.78	94.55
TOT	179	167	53	44	712	122	44	284	73	100	26	
%TOT	4.34	4.05	1.29	1.07	17.28	2.96	1.07	6.89	1.77	2.42	0.63	94.20

NOTE (1) Total percentages are cumulative over this and previous mission tables

TABLE 7 SQUADRON SORTIE STATISTICS

SQDN	TOTAL SORTIES	NIGHT SORTIES	AVG # CYCS PER SORTIE	STD DEV	AVG A/C PER EVENT	STD DEV
VF	445	217	1.13	0.489	1.87	0.463
VF	443	212	1.13	0.464	1.83	0.430
VFA	497	246	1.05	0.351	1.95	0.566
VFA	502	246	1.04	0.389	1.89	0.597
VA	598	299	1.03	0.176	1.34	0.497
VAQ	255	124	1.09	0.311	1.085	0.279
VS	339	187	1.44	0.527	1.063	0.243
VAW	178	88	1.754	0.634	1.01	0.130

While some of the mission areas are aircraft specific, such as anti-air warfare missions like AIC, ACM and CAP, the information in Table 8 shows how the shared missions are divided among those capable of doing them. The percentages in Table 8 are, again, totals of sorties that had a given mission assigned with no weight given to whether the mission was assigned as a primary or secondary mission. This explains why neither the columns nor rows sum to 100. The numbers should only be used for comparison within the airwing. The OTH column accounts for unique mission assignments, a conglomerate of rarely flown missions.

TABLE 8 MISSION PERCENTAGES BY SQUADRON

	ACM	AEW	AIC	ASW	BMB	CAP	CQ	DACT/M	ESM	FCF	LWLVL	MAS
VF-1	7.19		39.3			17.1	6.52	5.62		2.25	1.12	9.66
VF-2	7.9		29.6			15.4	6.77	5.64		2.48	3.39	9.55
VFA-1	6.44		16.5		27.0	6.04	7.24	3.02			3.02	6.24
VFA-2	7.57		18.9		19.7	5.78	6.57	4.58			1.58	7.17
VA					24.0		6.04	4.87			1.85	
VAQ			1.57			11.0	6.27	4.71	38.4		2.35	15.69
VS				5.88	4.41		5.59				2.35	
VAW		86.0					7.87			6.18		

TABLE 8 MISSION PERCENTAGES BY SQUADRON CONTINUED

	MTNK	NAV	NVG	OTH	SSC	STK	STRF	SVCS	TARPS	TG/T	TNK	YOYO
VF-1		2.7		11.9	2.25	3.37	2.47			3.82		0.9
VF-2		3.16		5.87	3.61	2.03	4.29		9.93	2.71		
VFA-1			4.43	8.05	21.3	6.04				1.61		1.61
VFA-2			4.38	5.98	24.5	3.78				1.39		2.39
VA	6.71			6.21	33.7	2.68				1.01	30.7	
VAQ				9.02	21.2	3.92						
VS	37.35			3.53	49.1			4.44		5.0	29.7	
VAW				5.62	19.7					43.8		

1) Percentages in Table 9 represent total number of sorties having a mission as a primary or secondary mission.

Some interesting information is available in Table 8. Mainly, the distribution of certain primary mission areas within the airwing. The distribution of tanking sorties is an interesting example. There are only two aircraft that can provide organic airborne tanking to the rest of the airwing, the A-6E and S-3A. Approximately 37 percent of A-6E sorties were tasked with either the mission tank (MTNK) or recovery tank (TNK) mission compared to over 65 percent of S-3A sorties. When more data is available through saving airplans in an easily analyzed format, the ship and airwing will have a way to compare shared missions to ensure an equitable distribution.

The information that proved valuable for the model choice from both Tables 5 and 7 was the large number of possible mission combinations. Narrowing the number of mission areas to 23 left an average of only seven percent of each squadron's total sorties unaccounted for. This led to the conclusion that mission data is much too fluid to account for fully in a prototype model.

Some of the information from Table 8 may be confusing to the reader unfamiliar with carrier and airwing operations. One such area is the high percentage of E-2C (VAW) sorties scheduled for Touch and Goes (TG/T). This is common among most airwings. The E-2C is a dual piloted aircraft. To maintain night currency, it is common for one pilot to fly a touch and go and the other pilot fly the final landing. When night sorties are scarce, this technique is used by the airwing to boost VAW pilot night currency. Another point brought out by Table 8 is seen in the Tactical Air Reconnaissance Pod (TARPS) mission column. It is common for only one VF (F-14A) squadron to fly all TARPS missions. This is due to the aircrew training required for the

TARPS mission and the cost of the TARPS pods. The extra TARPS sorties flown by VF-2 were partially compensated for in the AIC mission area. VF-1 flew approximately 10 percent more AIC missions than VF-2.

D. RESULTS SUMMARY

The airplans obtained proved to be good candidates for future use. The distribution of sorties and missions follows the necessary requirements for readiness as prescribed in the joint AIRPAC/AIRLANT Training and Readiness Instruction. The analysis of the breakdown of day and night sorties throughout the airwing showed these airplans provide an equitable mixture and a chance for each squadron to maintain a maximum number of night current pilots, without flying an unnecessarily high number of total sorties at night. The airplans analyzed had approximately 50 percent of the sorties flown recovering at night. While this might seem a little higher than required, it is not unreasonable. The sortie per cycle rate was found to be 15 during the day and 14 at night which confirms known limitations applied by AIROPS. Deviations in number of cycles, sorties and sorties per cycle were found to be small.

Mission data showed a relatively small percentage of sorties being launched with secondary and tertiary missions, 25 percent and 3 percent respectively. Mission analysis also confirmed standard operations in numerous areas such as; TARPS, Touch and Goes, and Airborne Tanking. Approximately 95 percent of sorties flown from the carrier can be accounted for using 23 missions. This number is reduced when

considering only a single aircraft type but the number of mission combinations is still quite large. This fact will affect the feasibility of different prototype models.

IV. MODEL RECOMMENDATIONS

A. POSSIBLE SOLUTIONS

Several common operations research techniques, each with its strengths and weaknesses, exist for solving scheduling oriented problems. One of the most useful techniques is mathematical programming. Two possible mathematical programming approaches will be discussed.

1. Expected-Value Coefficient Linear Program

A linear/integer program could be used to solve the problem of the airplan production. In this case, the averages for total sortie and mission area breakdowns gathered in Chapter III would be used as constraint coefficients for a linear program. The division of total sorties and day/night mixture within each squadron could be treated as constant over a long period of time (a deployment, for example). This method would, given proper formulation, provide an optimal mixture of sorties over an average number of cycles. The basic template could then be modified by Strike Operations to meet the actual tasking for the next day.

2. Interactive Linear Program

The analysis from the Chapter III also suggests an interactive linear program or optimization model. Unlike the expected value model, this would take, as input, the known data for the next day's airplan. That information could include:

- Number of day cycles.
- Total number of sorties allowed.
- Number of up (flyable) aircraft for each squadron.
- Mission priorities.
- Division of sorties within the airwing.
- A small amount of historical data.

An interactive program could then formulate a unique linear program each day. A model of this type would be very dynamic. An airplan could be formulated almost to completion.

3. Discussion of Mathematical Programming Approaches

These two approaches were seriously considered for the prototype model. A major portion of the analysis was directed towards designing an adaptation of the linear program found in Reference 4 which could be adapted to either approach. The interactive linear program was chosen initially. It was quickly determined that the amount of interaction adversely impacted the size and complexity of the problem. The linear program quickly grew very large. Initially, this did not seem to warrant discarding the idea. Eventually, however, as the results approached realistic conditions, the problem formulation grew to a size that was unmanageable for the expected computing power of the intended user. Thus, the rejection of the interactive linear program solution.

The interactive linear program problem violates two of the requirements discussed in Chapter I. The amount of interaction required, found to be considerable to make the linear program realistic, violates the simplicity requirement, making it difficult for the program to be introduced and used in the fleet. The sheer size of the problem violated the cost constraint. The optimization package in Quattro Pro was unable to handle either of the above discussed linear programs. A commercial add-on program that works within Quattro Pro was investigated but the version required to handle even a moderate-sized airplan cost $1000 per copy.

The expected value model would provide only one airplan template for use by Strike Operations unless there existed several different linear programs to handle a limited mixture of total sorties and number of cycles allowed. This would require a different formulation for each template. The large number of possible missions and mission combinations preclude this approach. As discussed in Chapter III, 94 percent of the missions are accounted for with 23 mission areas. The possible combinations quickly increase the size and complexity of a linear program.

While neither of the optimization programs solved the problem, they were helpful in gaining insight into the carrier airplan. The interactive linear program in particular could be a valuable tool for in-depth airplan analysis.

4. Iteration Method

A computer program could be written to generate all possible airplans for a given number of cycles and sorties. This brute force approach would produce a very large number of possible airplans. The initial number of airplans could be reduced by

placing some reasonable constraints on the generation program. The output from the initial program could then be run through a number of culling sub-programs which would sort through and pare down the list until a reasonable number of candidate airplans remained. This method is an excellent project for a Computer Science thesis but is rejected here for size and complexity reasons.

B. INTERACTIVE DATABASE SEARCH MODEL

A approach found to best meet the simplicity and cost requirements, while achieving the established goal, to assist ASTKE by reducing the repetitive work he must currently accomplish, proved to be an interactive database search model. The basic procedure for this model is:

- Characterize the airplan in a concise way that benefits the production process.
- Place the characterizations into a database that can be searched and sorted quickly and easily.
- Provide ability to retrieve a sample of a few airplans from what would be a larger more cumbersome database.
- Provide a means to make minor changes to the chosen airplan template and save it for future incorporation into the database.

1. Assumption

As discussed in Chapter II, several previously flown airplans were entered into the database supported by both Paradox 3.5 and Quattro Pro 3.0. Constraints, such as number of sorties per cycle, amount of airborne fuel available, and the concern over equitable division of available sorties, are assumed to be at least partially accounted for if the proposed airplan for the next day is based on an airplan that has already undergone

the scrutiny necessary for approval. The analysis backed this assumption. The airplans used for the initial database were composed using an equitable spread of sorties.

2. Model Basics

A basic description of the chosen model follows. A more user-oriented version can be found in Appendix C. The idea behind the database search model is that Strike Operations be given an initial database which includes several "standard" fly days for an aircraft carrier. Through the process of updating of the database and the search file, the database is eventually tailored to the way the individual ship and airwing do business. After a few months of flying the original database could be purged, leaving only that ship's airplans present.

The general flow through the model is accomplished first in Paradox where the user selects a candidate airplan via menu driven queries. The date associated with that candidate airplan is the file name for that airplan in Quattro Pro. The spreadsheet file or files are then viewed in Quattro Pro. Once the best airplan is chosen it can be altered to meet specific tasking. Each stage of the application will be discussed.

3. Paradox 3.5

The Paradox portion of the application is menu driven queries that prompt the user to select an airplan based on a number of different criteria. Figure 6 is a diagram of the menus. The menus were constructed using Paradox's Personal Programmer Feature, which allows database queries to be saved as menus. The queries defined by the interactive menu selection and user inputs ensure selection of the airplan which best meet the tasking for the next day.

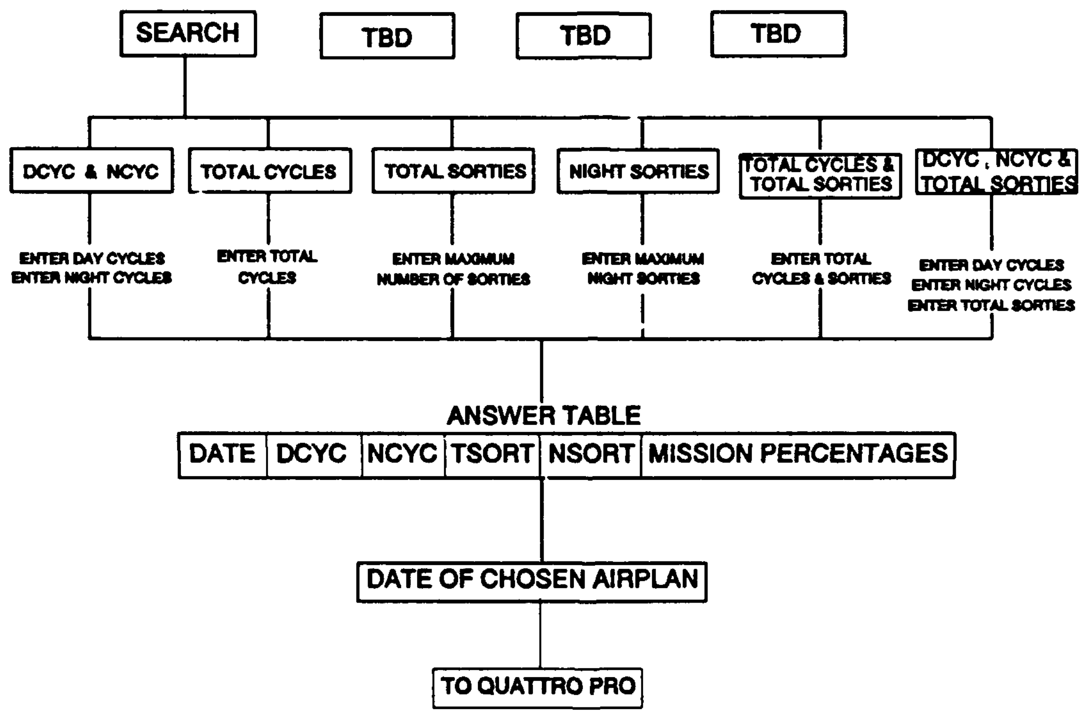


Figure 5 Paradox Menu Structure

The choices for airplan selection are made by querying the inputs commonly made at the beginning of airplan construction. The six query choices are:

- Number of day cycles and night cycles.
- Number of total cycles.
- Number of total sorties.
- Number of night sorties.
- Number of total cycles and total sorties.
- Day cycles, night cycles and total sorties.

Each of the queries above returns a table of airplans that meet the desired inputs. Additional information characterizing the airplans is available in the resulting query answer table. Along with the date corresponding to the airplans are a number of mission area percentages. These percentages reflect the number of sorties on that airplan that have that mission as a primary <u>or</u> secondary mission. This further distinction gives the scheduler another method of narrowing the possibilities.

If queries are unsuccessful or it is determined by ASTKE that flight operations for the next day will be very specific, a number of blank templates are available for constructing an airplan from scratch. These will be discussed in the next section. The result from Paradox is simply a date or number of dates corresponding to Quattro Pro file names. The user uses these dates to choose a template for the next day's airplan.

4. Quattro Pro

The portion of the application designed in Quattro Pro consists of two file types modifiable to meet the needs of the ASTKE. Both are airplan templates, one is a previously flown airplan, the other is a blank airplan template. The end result is the same, an airplan that can be published directly from the computer.

A series of macros and spreadsheet functions help ASTKE with the more tedious tasks. The macros and functions can be seen in Appendix B. They accomplish line drawing and computation of sortie totals for each squadron and each cycle. This is accomplished by using the ability to name and hide blocks in the spreadsheet. Where quantities are involved, named blocks and Quattro Pro functions are used to calculate the appropriate values. Figure 6 depicts the layout of named blocks and hidden columns used in calculations. The blocks are summed vertically and horizontally to receive cycle launch and recover totals, squadron day and night sortie totals, and, overall total day and night sortie totals. Presently this is done by hand and must be done each time a change is made to the airplan. Since the total number of sorties is usually an externally imposed constraint, an updated total relieves ASTKE of the need to consistently recalculate sortie and cycle totals.

C. CONCLUSIONS

While the interactive database model meets the goals and requirements outlined in Chapter I, it has some limitations namely limits of the macro language and difficulty in data extraction. They are lessened with spreadsheet experience, but not easily.

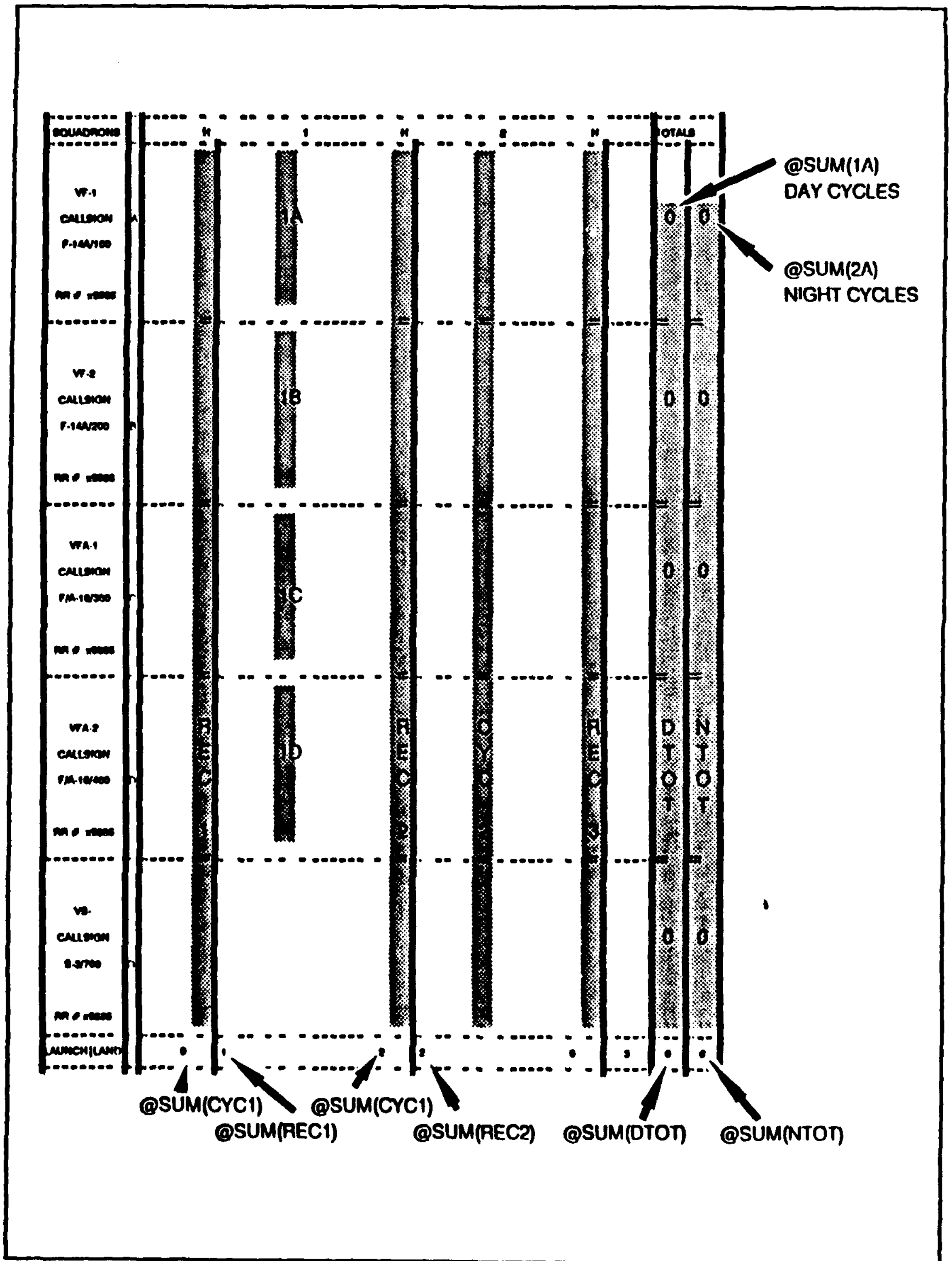


Figure 6 Quattro Pro Block Structure

The goal is to provide a model to ASTKE for evaluation. It is accomplished. The prototype model can be experimented with at little cost to the user. If the concept is accepted, a final model can be constructed using lessons learned from the prototype. Once the prototype is in use, an extensive database of airplans will be available for further analysis.

V. CONCLUDING REMARKS

A. MODEL USE

The interactive database model described in Chapter IV will be provided to the Assistant Strike Operations Officer of the USS Abraham Lincoln for use during an upcoming work-up and deployment cycle. The results will determine whether further development of this approach is warranted, or if prototype development of one of the other models discussed should be investigated.

Undoubtedly, the model will relieve the Assistant Strike Operations Officer of some repetitive tasks. This alone does not warrant development of a final model. There could be other problems introduced. After the trial period, the Strike Operations team should be able to provide valuable inputs to a final model.

B. PROTOTYPE REFINEMENTS

One refinement to be accomplished during fleet introduction will be a Quattro Pro macro to assist ASTKE in drafting the Air Tasking Order (ATO) that is promulgated to the warfare commanders. This macro will also enable ASTKE to form the DAILY files necessary to update the database search file. This macro is a mirror image of the macro used to build the airplan templates. This will not be done, however, until the model is more thoroughly tested.

C. FURTHER RESEARCH PROJECTS

If it is determined that the database approach satisfies the needs of Strike Operations, the final model should be a stand-alone program designed specifically for the task of writing the airplan. The prototype model described in Chapter IV is limited by the software chosen. The spreadsheet environment is adequate for testing the idea but a program written with the single goal of airplan production would be much better. A student in the Computer Science Department should be sought to accomplish this for thesis work.

In addition to a stand-alone airplan production program, another thesis project is possible. A more intricate database structure could be developed to work along with the final model, extracting significant data. Once again, the choice of software present limits the data collection. Data is not easily extracted. A substantial amount of spreadsheet knowledge is needed to extract the data from the airplan files. Macros can be written to accomplish the data extraction but the macro language of Quattro Pro is not as flexible as a structured programming language. The database structure would be an excellent project for a thesis student in the Information Systems curriculum. If students from both the Computer Science and Information Systems curricula could be encouraged to work together, the final product would be valuable to a number of Navy commands.

D. RECOMMENDATIONS

From numerous conversations with former and current Strike Operations and Assistant Strike Operations Officers, it is apparent that a major portion of the airplan

production problem is not its actual construction. Often, it is the interactions throughout the ship, airwing and battlegroup that force the airplan to be published at late hours. Examples of such factors are changes in forecasted weather or an unforeseen loss of assets (aircraft down for maintenance). These interactions must be dealt with individually and prioritized. In most cases, their impact can be minimized or eliminated. For any automation process to have a noticeable impact on the publish time of the airplan, the process itself must be revised to some extent.

Throughout the day, numerous inputs are made that force changes to the next day's flight operations. The changes come from many areas as discussed in Chapter I. The impact of the changes can vary from minor mission changes to major restructuring of flight operations for the next day. The major changes are for the most part uncontrollable. They usually reflect a change in battlegroup tasking either by the battlegroup commander or fleet commander. Revised tasking can be promulgated at any time and is generally accepted as the nature of the business. These problems must be addressed at a level much higher than will be impacted by this thesis.

The changes that can be controlled are the ones that reflect operations internal to the battlegroup, mainly, combined warfare commanders and individual squadron's needs or wants. Many of these changes can be minimized by establishing guidelines for changes to the airplan: i.e. who can make these changes and when.

1. Airwing Planning Session

It is recommended that squadron representatives meet with ASTKE or the Airwing Operations Officer in a short planning session for the next day's events after

warfare commander tasking has been received. A meaningful planning session would force squadron inputs to be made early in the day. Once the tasking requirements are met, secondary missions could be added to allow squadrons to accomplish necessary training. The analysis showed only 27 percent of the sorties launched were multi-mission sorties. While some missions require a complete sortie to accomplish, many can be accomplished as secondary missions without interfering noticeably with the primary mission.

2. Limit Change Opportunities

Another recommendation is to set a deadline when all routine airwing airplan changes must be made. The intent is to force squadron operations officers to make their changes earlier in the day and to reduce the number of unnecessary changes.

Limiting the ability to make changes to the airplan throughout the day could be detrimental to the quality of the final product. If legitimate changes are suppressed for the sake of publishing the airplan at an earlier time, the airplan will not reflect what will actually happen. The changes will be made during execution and what is actually flown will not reflect what was scheduled. If the recommendations stated earlier are implemented, this problem must be watched for and handled carefully.

APPENDIX A - LIST OF MISSION AREA ACRONYMS

- ACM Air Combat Maneuvers.
- AEW Airborne Early Warning.
- AIC Air Intercept Control.
- ASW Anti Submarine Warfare.
- BMB Bombing.
- CAP Combat Air Patrol.
- CQ Carrier Qualification.
- DACT/M Dissimilar Air Combat Maneuvers/Training.
- ESM Electronic Support Measures.
- EX Exercise (Any Type).
- FCF Functional Check Flight, Post Maintenance Checkflight.
- LWLVL Low Level Navigation.
- MAS Maritime Air Superiority (Long Range CAP).
- MTNK Mission Tanker.
- NAV Navigation.
- NVG Night Vision Goggles.
- SSC Surface Search and Communication.
- TG/T Touch and Go then Trap.
- TARPS Tactical Air Reconnaissance Pod.

- TNK Recovery Tanker.
- SVCS Services Provided to Another Asset.
- STK Strike (actual or simulated).
- YOYO Launch and Recover on Same Cycle.
- OTH Other.

APPENDIX B - ANALYSIS TOOLS

A. QUATTRO PRO 3.0 ANALYSIS TOOLS

Numerous "@" *functions and macros* were used to extract data from each of the file types discussed in Chapter III. For those unfamiliar with the spreadsheet environment "@" functions are mathematical or logical functions that are applied to a cell or block of cells in a spreadsheet. Macros are small programs written in a language specific to the software applications in use. Macros call menu selections or "@" functions when they are activated. Quattro Pro macros are activated by naming a macro in one of a number of ways. All macros used in the analysis were named using the \"letter" option in Quattro Pro. The macros are then activated by depressing the ALT key and the letter name simultaneously. Some of the macros and "@" functions used in the analysis are listed below for further use. [Ref 6]

1. Mission Selection

This function was used to extract the number of each mission type for individual sorties. It compares the primary and secondary mission columns with a column header it returns a 1 if there is a match, a 0 if not.

```
@IF (@EXACT($E2,K$1),1,@IF(@ISSTRING($F2),@EXACT($F2,K$1),0))
```

The next function was used to gather information concerning squadron statistics from the OVERALL file. It compares the column header with the squadron letter cell. It returns a 1 if there is a match, a 0 if not.

```
@IF ( @EXACT($E2,K$1),1,0)
```

The inner product or dot product function (@SUMPRODUCT('COL1','COL2') can be used on the resulting column of ones and zeros with other columns yielding the number of sorties with a given trait, such as:

- launch or recover cycle.
- number of cycles flown.
- number of aircraft per event.

2. DAILY File Modification Macro

The following macro was used to restructure the daily airplan files. The structure of these files, as originally entered into the database was not readily transferable to airplan format.

```
{HOME}
{/ Column;Insert}A1..J1~
{HOME}{RIGHT 1}{;CATENATES CALLSIGN COMPONENTS}
@STRING(K1,0)&L1&@STRING(M1,0)~
{/ BLOCK;COPY}B1~
B2..B150~
{HOME}{RIGHT 1}
{/ Block;Values}B1..B150~
B1..B150~
```

```
{; JOINS MULTIPLE MISSIONS TO ONE FIELD}
{HOME}{RIGHT 5}{;MOVE TO CELL F1}
@IF((@ISSTRING(O1)#AND#@ISSTRING(P1)),(O1&","&P1),O1)~
{/ Block;Copy}F1~{;COPIES JOINED MISSIONS TO APPROPRIATE
CELL}
{;MOVES INFORMATION TO APPROPRIATE PLACES}
F1..F150~
{HOME}{RIGHT 5}~
{/ BLOCK;VALUES}F1..F150~
F1..F150~
{HOME}
{/ BLOCK;MOVE}N1..N150~
D1..D150~
{/ BLOCK;MOVE}Q1..Q150~
I1..I150~
{/ BLOCK;MOVE}R1..R150~
J1..J150~
~
```

3. Event Transfer Macro

This macro was used in transferring the events from the DAILY files to the airplan templates. A slight modification to this macro would enable copying airplan information from airplan to DAILY file format.

```
{/ Block;Copy}{;COPY BLOCKS TO AIRPLAN TEMPLATE (\C)}
{RIGHT 7}~
{NEXTWIN}{DOWN 6}{?}
~
```

4. Statistics Gathering

The following macro creates columns for gathering information on squadron operations. It is formatted for usc on DAILY files.

```
{HOME}
{/ Row;Insert}~
{HOME}
{RIGHT 20}
A{RIGHT}
```

```
B{RIGHT}
C{RIGHT}
D{RIGHT}{;FORMS COLUMNS FOR EACH SQN}
E{RIGHT}
F{RIGHT}
G{RIGHT}
H{RIGHT}
{LEFT 8}
{DOWN}
@EXACT(U$1,$L2)~
{/ Block;Copy}~
U2
{?}~
{?}{;USER INTERACTION}
A
{RIGHT}B
{RIGHT}C
{RIGHT}D
{RIGHT}E{;COPIES COLUMN HEADERS AT BOTTOM OF FILE}
{RIGHT}F
{RIGHT}G
{RIGHT}H
{LEFT 7}
~
```

B. QUATTRO PRO AIRPLAN PRODUCTION TOOLS

1. Recovery Column Reveal and Hide Macros

The following macros are used to reveal and hide the columns used in calculating recoveries for each cycle.

```
{/ Column;Hide}~{right 7}~{;HIDE RECOVERY COLUMN (\H)}
~

{/ Column;Display}{right}~{right 8}~{;REVEAL RECOVERY
COLUMN (\R)}
~
```

2. Line Drawing Macros

The following three macros were written to aide ASTKE in altering the airplan templates for specific tasking or if an airplan is being composed from scratch. These macros not only draw the appropriate lines for single, double and triple cycle sorties they also place the appropriate number of sorties recovering in each recovery column.

```
-~{right 2}~{;SUBROUTINE CALLED BY LINE DRAWS}

{FOR C4,1,4,1,A2}~{;SINGLE CYCLE LINE DRAW (ALT S)}
{LEFT 5}{/ BLOCK;COPY}~
{RIGHT 4}~
~

{;DOUBLE CYCLE LINE DRAW (ALT D)}
{FOR D11,1,4,1,A2}~
{FOR D12,1,7,1,A18}~
{LEFT 8}0~
{LEFT 4}{/ BLOCK;COPY}~
{RIGHT 12}~
~

\-~{RIGHT}~{;SUBROUTINE CALLED BY MULTI-CYCLE LINE
DRAWS}
{;TRIPLE CYCLE LINE DRAW (ALT T)}
{FOR D21,1,4,1,A2}~
{FOR D22,1,7,1,A18}~
{FOR D23,1,8,1,A18}~
{LEFT 8}0~
{LEFT 8}0~
{LEFT 4}{/ BLOCK;COPY}~
{RIGHT 20}~
~
```

APPENDIX C - USER GUIDE

A. INTRODUCTION

The following is designed to give the prospective user the background needed to utilize the interactive database model described in Chapter IV. Each facet of the model will be addressed. This appendix along with Appendix B of macros and functions should be enough to explain the workings of the application for basic use.

The application uses two commercially available software programs Paradox 3.5 and Quattro Pro version 3.0 or higher. All program specific menu commands in this document will be Quattro Pro commands. Menu commands and file names will be made in all capital letters, such as FILE/SAVE and MACRO1.WQ1. Macro commands will be preceded by ALT then the letter corresponding to the named macro, such as ALT A. This is how macros are activated in Quattro Pro. If another spreadsheet program is being used, the commands will be different. [Ref 5]

The general flow through the application is accomplished first in Paradox where the user selects a candidate airplan via menu driven queries. The date associated with that candidate airplan is the file name for that airplan in Quattro Pro. The spreadsheet file or files are then viewed in Quattro Pro.

Once a decision is made on which of the templates is to be used that template should be copied with a new file name that corresponds to the date of the new airplan. This is accomplished by using the macro ALT Z. It is important to copy the airplan prior to making any changes. This keeps the initial database constant until it can be

updated. If changes are made to the template airplans the database queries will provide erroneous information. Each aspect of the application will be addressed separately.

B. Paradox 3.5

The Paradox portion of the application is menu driven queries which allow the user to select an airplan based on a number of different criteria. The menus are structured to walk the user through the selection process. A diagram of the menus can be seen in Figure 5. The menus were constructed using Paradox's Personal Programmer Feature. The user should enter Paradox via the PPROG directory [Ref 7].

1. Queries

The queries defined by the interactive menu selection and user inputs allow the user to select an airplan that best meets the expected tasking for the next day. Choices are determined by the inputs commonly made at the beginning of airplan construction. The six query choices are structured as follows:

- Number of day cycles and night cycles.
- Number of total cycles.
- Number of total sorties.
- Number of night sorties.
- Number of total cycles and total sorties.
- Day cycles, night cycles and total sorties.

Each of the queries returns a table of airplans that meet the desired inputs. Also note, where sorties are involved the constraints are maximums but in determining the number of cycles the numbers must be exact matches.

2. Mission Distinction

Along with the date for each of the airplans are a number of mission area percentages. These percentages reflect the number of sorties on that airplan that have that mission as a primary or secondary mission. This gives the scheduler another method of narrowing the possibilities. Once a candidate airplan has been chosen, it can be found in Quattro Pro spreadsheet format with file name MMDDYY.WQ1.

C. Quattro Pro

1. Macro File

The airplan files the scheduler will be using are saved as Quattro Pro worksheets. Upon entering the Quattro Pro environment the MACRO.WQ1 file should be opened. This file contains the macros used to aid the production process. The MACRO.WQ1 file is a Quattro Pro macro library. When a macro is activated Quattro Pro first looks in that spreadsheet for the commands. If they are not present there, Quattro Pro looks for an open macro library. If this file is not open the macros will not run. [Ref 6]

2. Daily Airplan File

The file names for the airplan worksheets are of the form MMDDYY.WQ1. As suggested earlier the original airplan files should not be altered. Neither should the

blank templates. The file should be opened and viewed to see if the airplan meets the necessary requirements for the next day. Once an airplan template is selected the ALT Z macro should be used. Once again, this is to maintain integrity of the database queries. Once this is done, the file has a new name and can then be altered.

3. Hidden Columns

Prior to changing the airplan, there are a number of hidden columns that need to be revealed. This is accomplished by positioning the cell pointer on the left side of the first cycle vertical line, as seen in Figure 6. From this position use the macro command ALT R (REVEAL) repeatedly until all hidden columns in the airplan have been revealed. The hidden columns contain an H in the cycle row to remind the user they need to be hidden when the airplan is complete. The columns are hidden by placing the cell pointer in the first column to be hidden and using the ALT H (HIDE) macro repeatedly until all recovery columns are hidden. The hidden columns contain the number of aircraft recovering in a particular cycle, hiding them is strictly for aesthetics. Placing the number of aircraft recovering in these columns allows the spreadsheet program to calculate the sortie totals at the bottom of the airplan.

4. Modification

With the recovery columns revealed, the airplan can be altered to suit the next day's tasking. It is imperative, for calculation purposes, that the number of sorties launching and recovering be placed in the correct column. This is easily determined since all columns in the airplan templates are defaulted to contain labels except the quantity and recovery columns. Whether a column is considered a label or not can be

seen in the input line at the top of the spreadsheet. The word Label will be the first word in the input line in all columns except those used in calculations. The sortie counts are made by using a series of named blocks. The general layout of these blocks is given in Figure 6. Launch and recovery totals are calculated by summing over the named blocks. If letters appear in these blocks an ERR message will appear where the total should be.

5. Sortie Lines

If an airplan is begun from one of the provided blank templates, or major revisions are made to an existing airplan, there are three other macros designed to speed up the process. ALT S, ALT D, and ALT T are line drawing macros in MACRO.WQ1 for single, double and triple cycle sorties respectively. They are utilized by placing the cell pointer in the column preceding the callsign and activating the appropriate macro for the duration of the sortie. The lines are drawn for the correct duration and the number present in the quantity column is placed in the appropriate recovery column.

LIST OF REFERENCES

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